system is further increased by capturing additional waste heat from the combustion chamber 25. The combustion chamber 25 is enclosed in a double shell heat exchanger 90. In the version shown, the hot compressed air 11 exiting the compressor 10 passes through the shell 92 immediately surrounding the combustion chamber 25 before it enters the combustor 25. The cold water 41 is fed to a second shell 94 which surrounds the first shell 92. In this manner the air 11 absorbs additional heat normally lost from the combustor 25 and the incoming water 41 absorbs some of the heat from the compressed air 11. An additional benefit, since the air 11 is at an elevated pressure, is that the pressure differential across the combustion chamber 25 wall (i.e. the difference between the combustor interior and ambient conditions as in FIG. 5 or the difference between the combustor interior and the compressed air 11 is significantly reduced, thus reducing the stress on the combustor wall from the combination of high temperature and high pressure. The water 41, after passing through the combustion chamber outer shell 94, then proceeds through the condenser 62 and the heat exchanger 73 to acquire the desired injection temperature. Care is taken to maintain the water under pressure possibly as high as 4000 psi so that, as the water is heated, it does not convert to steam before it is injected into the combustion chamber 25 which is at a higher temperature and, in most instances, a lower pressure than the superheated water 41.

Purification of contaminated waste products or treatment of solid, liquid and gaseous waste products from commercial processes resulting in useable products with power production as a by-product are also potential applications of an engine employing the VAST cycle. Waste water from dried solid waste products may be used in the present invention, resulting in filtered, useable water as one byproduct. The combustible materials are additional fuel for burning in the combustor 25 and the inorganic dried waste products may then be used to create fertilizers. As is apparent, other chemicals can be extracted from solid and liquid products using the present invention. Sewage treatment is also an application. Other applications include water softening, steam source in conjunction with oil field drilling operations and well production, recovery and recycling of irrigation water along with fertilizer and minerals leached from the soil, municipal solid waste, etc.

2. Aircraft Engines

The VAST cycle described about, particularly when operated with recycled water, is particularly efficient and has a relatively low fuel consumption when used in commercial aircraft which normally operates at 30,000 to 40,000 feet. At such elevations ambient pressure is 0.1 to 0.25 atmospheres or lower and ambient temperature is well below 0° F. Examples 5–7 open cycle data illustrate the benefit of lowering turbine exit pressure. To generate turbine exit pressures below atmosphere, such as when operating the system at sea level, a vacuum pump on the turbine exit is necessary. This pump, which consumes energy generated by the system, reduces the usable energy and efficiency of the system.

Elimination of the turbine exit vacuum pump by operating in an environment with pressures less that atmosphere, such as at elevations greater than about 30,000 feet, increases the usable power output of the system, and therefore, reduces fuel consumption. Further, if the water in the system is to be recycled, the ambient air temperature can be used to condense and cool the exiting gas stream and separate the water for recycling reducing the amount of energy used to recover the heat.

3. Steam Generation and Steam/Power Cogeneration

It is also contemplated that the combustor and its control system, along with a suitable compressor can be used without the power turbine solely for the generation of high temperature, high pressure steam, the generation of potable water, or the recovery of valuable inorganic materials dissolved in the water. Alternatively, one or more gas and/or steam turbines sized to produce a desired amount of electrical energy can be coupled to the combustor to deliver electrical energy as well a mix of high temperature, high temperature steam as a side stream directly from the combustor.

While various embodiments of the present invention have been shown for illustrative purposes, the scope of protection of the present invention is limited only in accordance with the following claims and the spirit and scope of the appended claims should not be limited to the description of the preferred versions contained herein.

What is claimed is:

1. A power generating system comprising:

a compressor configured for compressing ambient air into compressed air having a pressure greater than at least about four atmospheres and an elevated temperature;

a combustion chamber connected to the compressor, wherein the combustor is configured to receive flow of compressed air from the compressor;

fuel injection means for injecting fuel into the combustion chamber;

liquid injection means for injecting a vaporizable non-flammable liquid into the combustion chamber;

a combustion controller for independently controlling the quantity, pressure and temperature of the compressed air, the fuel delivered to the fuel injection means, and the vaporizable liquid delivered to the liquid injection means so the injected fuel and at least a portion of the compressed air is combusted and the injected liquid is transformed into a vapor in the combustor to create, in the combustion chamber, a working fluid consisting of a mixture of unburned compressed air components, fuel combustion products and the vapor during combustion at a predetermined combustion temperature; and

a work engine coupled to and supplied with the working fluid formed in the combustion chamber.

2. The power generating system according to claim 1 further including an ignition sparker for igniting the injected fuel and compressed air.

3. The power generating system according to claim 1, wherein the power generating system further including condenser means for condensing a desired portion of the vapor from the working fluid and exhaust means for exhausting the remaining portion of the working fluid.

4. The power generating system according to claim 1 further including condenser means for condensing the vapor from the working fluid back to a vaporizable liquid, recycle means for delivering said vaporizable liquid to the liquid injection means, and exhaust means for exhausting the remainder of the working fluid to the compressor for recompression.

5. The power generating system according to claim 1 further including one or more additional combustion chambers receiving the compressed air, fuel and vaporizable non-flammable liquid configured such that working fluid from all combustion chambers is delivered to one or more work engines.

6. The power generating system according to claim 1 wherein the work engine receiving the work fluid is selected

from the group consisting of one or more of a steam turbine, gas turbine, reciprocating, Wankel and cam engine, and shaft drive units.

7. The power generating system according of claim 1, wherein the compressor and work engines are turbine type devices, and wherein said devices are connected by at least one shaft.

8. The power generating system according to claim 1, wherein the combustion controller controls the combustion temperature using information transmitted from temperature detectors located in the combustion chamber.

9. The power generating system according to claim 1, wherein the combustion control means controls the liquid injection means and fuel injection means during combustion such that the weight of injected liquid is at least about two times the weight of injected fuel so that the quantity of delivered vaporizable liquid is controlled to maintain the average temperature of the working fluid delivered to a desired work engine to a desired operating temperature.

10. The power generating system according to claim 9, wherein the combustion control means controls the air flow and fuel injection means such that the ratio of weight of injected fuel to weight of injected air is from about 0.03 to about 0.066 during combustion.

11. The power generating system according to claim 10, wherein the combustion controller independently controls the average combustion temperature and the fuel to air ratio.

12. The power generating system according to claim 9, wherein the combustion temperature is controlled by the combustion control means so that the air to fuel ratio is selected to obtain stoichiometric burning and the temperature of the working fluid is adjusted by controlling the delivery of the quantity of non-flammable vaporizable liquid, the temperature adjustment being provided substantially only by the latent heat of vaporization of said liquid.

13. The power generating system according to claim 9, wherein at least about 95% of the oxygen in the compressed air is combusted in the combustion chamber.

14. The power generating system according to claim 9, wherein the pressure of the compressed air is maintained at a pressure of 4 to 100 atmospheres, while entropy of the engine is held substantially constant.

15. The power generating system according to claim 1, wherein the pressure of the compressed air is maintained constant while the temperature of combustion and the quantity of working fluid is varied, by the combustion controller by adjustment of the quantity of non-flammable vaporizable liquid fed to one or more liquid injection means located throughout the combustion chamber.

16. The power generating system according to claim 1 wherein all chemical energy in the injected fuel is converted during combustion into thermal energy, the non-flammable liquid is water, and vaporization of the water into steam creates cyclonic turbulence that assists molecular mixing of the fuel and air such that stoichiometric combustion is effectuated.

17. The power generating system according to claim 1 wherein the liquid injection means is a series of one or more nozzles located in the combustion chamber fed by a pressurized liquid supply.

18. The power generating system according to claim 1 wherein the liquid injected into the combustion chamber is water which is transformed into steam and the combustion products are cooled substantially, solely by the latent heat of vaporization of water.

19. The power generating system according to claim 18 wherein the injected water absorbs heat energy so that the temperature of the working fluid is reduced to that of a maximum operating temperature of the work engine.

20. The power generating system according to claim 18 wherein the injected water is transformed by way of a flash process into steam at the pressure of the combustion chamber without additional work for compression and without additional entropy.

21. The power generating system according to claim 18, wherein the engine is a power turbine powered by the working fluid consisting essentially of steam, unoxidized nitrogen, inert gases in the compressed air, carbon dioxide and non-flammable components of the fuel.

22. The power generating system according to claim 18, wherein the water injected is used to control the combustion temperature and the maximum operating temperature of the work engine and to prevent the formations of gases and compounds that cause or contribute to the formation of atmospheric smog.

23. The power generating system according to claim 1 wherein the fuel injection means comprises at least one nozzle located in the combustion chamber, said nozzle being fed by a pressurized fuel supply.

24. The power generating system according to claim 21 wherein the fuel supply is selected from the group consisting of diesel fuel, well-head oil, propane, natural gas, methane, gasoline, alcohol and mixtures thereof.

25. The power generating system according to claim 1 wherein the injected liquid is non-potable water, and further includes means in the combustor to remove inorganic materials from the water after vaporization and collect such inorganic materials from the combustor.

26. The power generating system according to claim 24 further including a condenser for collecting potable water after the non-potable water has been vaporized in the combustion chamber.

27. The power generating system according to claim 1 wherein during the operation of the engine in excess of a predetermined rpm, water injection and the portion of compressed air combusted is constant with respect to fuel as engine rpm increases, and during the operation of the engine between the first and a second predetermined rpm the water/fuel ratio and the air/fuel ratio increases, and below the second predetermined rpm, water/fuel ratio and air/fuel ratio are held constant.

28. The power generating system according to claim 27, wherein the ratio of water weight to fuel weight injected ranges from about 8 to 1 to about 1:1 as the rpm of the engine is increased.

29. A method of operating a power generating system comprising the steps of:

compressing ambient air into compressed air having a pressure of at least about four atmospheres, and having an elevated temperature;

delivering the compressed air into a combustion chamber;

injecting controlled amounts of fuel into the combustion chamber;

injecting controlled amounts of a non-flammable liquid into the combustion chamber;

independently controlling the amount of compressed air, the amount of fuel injected, and the amount of liquid injected so as to combust the injected fuel at least a portion of the compressed air and to transform the injected liquid into a vapor;

wherein a working fluid consisting of a mixture of a non-flammable components of the compressed air, fuel combustion products and vapor is generated in the

combustion chamber during combustion at a predetermined combustion temperature.

30. The method of claim 29 further including the step of igniting the fuel using an ignition sparker.

31. The method of claim 29, wherein the power generating system further includes the steps of condensing a desired portion of the vapor from the working fluid and exhausting the remaining portion of the working fluid.

32. The method of claim 29, wherein the power generating system further includes the steps of condensing the vapor from the working fluid, delivering at least a portion of the condensed vapor back into the combustor, and delivering at least a portion of the remainder of the working fluid to the compressor for recompression.

33. The method of claim 29 further including the step of delivering the working fluid to at least one work engine.

34. The method of claim 29, wherein the compressed air is further heated by contact within outer surfaces of the combustion chamber prior to being delivered into the combustion chamber.

35. The method of claim 29, wherein the amount of liquid and fuel injected is controlled during combustion such that the ratio of weight of injected liquid to weight of injected fuel is at least about two to one so as to control the average temperature in the combustion chamber to a deliver desired work engine operating temperature.

36. The method of claim 35, wherein the air flow and fuel injection is controlled such that the ratio of weight of injected fuel to weight of injected air is approximately 0.03 to 0.066 during combustion.

37. The method of claim 36, wherein the average temperature in the combustion chamber and the fuel to air ratio are independently controlled.

38. The method of claim 37, wherein the combustion temperature is controlled to obtain complete combustion of the fuel with the conversion of all carbonaceous material fed to the combustion chamber to CO_2.

39. The method of claim 35, wherein at least 95% of the oxygen in the compressed air is combusted in the combustion chamber.

40. The method of claim 35, wherein the pressure of the compressed air is maintained at a pressure of 4 to 100 atmospheres, while entropy of the engine is held approximately constant.

41. The method of claim 29, wherein the pressure of the compressed air is maintained constant while the temperature and quantity of working fluid is varied.

42. The method of claim 29 wherein all chemical energy in the injected fuel is converted during combustion into thermal energy and the vaporization of liquid creates turbulence in the combustion chamber to cause intimate mixing of the fuel and air such that complete combustion is effectuated.

43. The method of claim 29 wherein the liquid injected into the combustion chamber is water which is transformed into steam following injection into the combustion chamber and the temperature in the combustion chamber is controlled substantially totally by way of the latent heat of vaporization of such water.

44. The method of claim 43 wherein the quantity of injected water is chosen so as to absorb the heat energy caused by combustion sufficient to reduce the temperature of the working fluid to a desired work engine operating temperature.

45. The method of claim 43 wherein the injected water is transformed by way of a flash process into steam at a pressure of the combustion chamber without additional work for compression and without additional entropy or enthalpy.

46. The method of claim 43, wherein the working fluid is comprised substantially only of steam, unoxidized nitrogen, non-flammable components of the compressed air and fuel, and carbon dioxide.

47. The method of claim 43, wherein the water injection is used to control the combustion temperature and to prevent the formations of gases and compounds that cause or contribute to the formation of atmospheric smog.

48. The method of claim 29 wherein the injected fluid is non-potable water, and further including the steps of vaporizing the non-potable water in the combustion chamber and removing any contaminating materials dissolved in the non-potable water from the combustion chamber separately from the working fluid.

49. The method of claim 48 further including the step of condensing potable water from the working fluid after the non-potable water has been vaporized in the combustion chamber.

50. The method according to claim 29 wherein during the operation of the power generating system at greater than a predetermined rpm, liquid injection and the portion of compressed air combusted is held constant with respect to fuel as engine rpm increases, during the operation of the engine between the first and a second predetermined rpm, the liquid/fuel ratio and air/fuel ratio is increased, and below the second predetermined rpm, the liquid/fuel ratio and air/fuel ratio are held constant.

51. The method of claim 43 wherein cooling of the engine is effectuated with water and without dilution air.

52. A process of continuously delivering a working fluid to the exit of an engine combustion chamber, the working fluid having enhanced power generating capacity when compared with the working fluid produced by an engine operating only with a fuel and air feed, comprising:

a) creating a combustible mixture by continuously combining fuel under pressure and compressed air in the combustion chamber, the air being fed in a fixed ratio to the fuel, the fixed ratio providing air in at least a stoichiometric quantity,

b) igniting the combustible mixture to create a continuously burning flame which produces a hot gas stream of combustion products having a pressure at least as great as the pressure of the compressed air, and

c) injecting a vaporizable, non-flammable liquid into the hot gas stream to reduce the temperature of the hot gas stream, the liquid prior to being injected being maintained at a pressure in excess of the pressure in the combustion chamber to maintain the non-flammable liquid in a liquid state prior to injection into the combustion temperature, the injected inert liquid flashing to vapor immediately upon entering the combustion chamber, the combination of the hot gas stream and vapor constituting the working fluid, the quantity of inert liquid and the temperature of the inert liquid being selected to produce a preset temperature in the working fluid at the exit of the combustion chamber, the temperature and dwell time of the hot gas stream of combustion products being controlled to cause substantially full combustion of the fuel while the temperature of the working fluid is controlled to minimize formation of nitrogen oxides and maximize formation of carbon dioxide, the process continuing until the need for delivery of the working fluid ceases to exist.

53. The process of claim 52 wherein the quantity of compressed air entering the combustion chamber is slightly in excess of the stoichiometric amounts so that at least about 95% of the oxygen in the air is consumed in the burning of the combustible mixture.

54. The process of claim 52 wherein the liquid is water and the temperature of the working fluid exiting the combustion chamber is controlled to a selected temperature between about 750° F. and about 2500° F. by the injection of the water.

55. The process of claim 54 wherein the temperature of the working fluid exiting the combustion chamber is controlled to a selected temperature between about 1800° F. and about 2200° F. by the injection of the water.

56. The process of claim 54 wherein the temperature of the water just prior to injection is at a temperature not more than about 50° F. below that of the working fluid exiting the combustion chamber.

57. The process of claim 52 further including, after step c), directing the working fluid into a turbine power generator, at least a part of the working fluid exiting the turbine being used to heat the non-flammable liquid prior to injection into the working fluid.

58. The process of claim 57 wherein the fuel is diesel oil number 2, the f/a is 0.066, and for every 1 pound per second of air feed the turbine power generator produces in excess of 650 horsepower at a fuel efficiency in excess of about 36 percent and an sfc of less than about 0.36.

59. The process of claim 52 wherein the fuel is selected from the group consisting of diesel fuel number 2, ethanol, sulphur free heating oil, well-head oil, propane, methane, natural gas, gasoline and mixtures thereof.

60. The process of claim 57 wherein for every 1 pound per second of air feed the turbine power generator produces in excess of 750 horsepower at a fuel efficiency in excess of about 42 percent and an sfc of less than about 0.32.

61. The process of claim 52 wherein the inert liquid is non-potable water and the process further includes the collection of inorganic materials dissolved in the non-potable water in the combustion chamber and the conversion of the inorganic materials to a solid form.

62. The power generating system of claim 1 further including at least one heat transfer means positioned external and circumferential to the combustion chamber and extending along a substantial portion of the length of the combustion chamber such that the compressed air flows over external surfaces of the combustion chamber prior to entering the combustion chamber, the temperature of the compressed air being elevated by heat radiated from said external surfaces.

63. The power generating system of claim 62 wherein the heat transfer means comprises at least two contiguous circumferential chambers.

64. A power generating system comprising

a) a combustion chamber,

b) a work engine coupled to the combustion chamber,

c) fuel supply means for delivering fuel to the combustion chamber,

d) air supply means for delivering compressed air at an elevated temperature and at a constant pressure to the combustion chamber the amount of air being chosen so that at least about 90% of the oxygen in the air is consumed when burned with the fuel, the fuel and air being mixed in the combustion chamber,

e) control means to vary the quantity of air supplied to the combustion chamber and to adjust the amount of fuel supplied to the combustion chamber so that the fuel to air ratio remains constant,

f) a fuel igniter for igniting the mixture of fuel and air to produce a combustion vapor stream,

g) liquid supply means for delivering superheated water under pressure to the combustion chamber, the water being converted substantially instantaneously upon entering the combustion chamber to steam, the delivery and formation of steam creating turbulence and mixing in the combustion chamber resulting in a working fluid composed of steam, combustion products and non-flammable materials in the air and fuel, said working fluid being delivered to the work engine,

h) a combustion chamber temperature controller, said controller delivering the superheated water to the combustion chamber in quantities sufficient to maintain the temperature of the working fluid at a desired level, substantially all of the control of the temperature in the combustion chamber being derived from the latent heat of vaporization of the water introduced into the combustion chamber, and

i) heat exchanging means for transferring heat from the working fluid exiting the work engine to the water, said heat elevating the temperature of the water from a feed temperature to the desired temperature for delivery to the combustion chamber.

65. The process of claim 64 also including the step of delivering additional non-flammable liquid to the compressed air prior to introduction of the compressed air into the combustion chamber.

66. The process of claim 64 wherein the compressed air is mixed with the fuel in at least two stages such that a portion of the air is mixed with the fuel, the fuel is ignited and then the remainder of the air is added to the fuel at a point downstream of the fuel igniter.

67. The process of claim 66 wherein about 50% of the compressed air is mixed with the fuel in a first zone of a burner at one end of the combustion chamber, said mixture of air and fuel is ignited to produce a fuel rich flame, about 25% of the air is added to fuel rich flame in a second zone of the burner located down stream from the first zone, about 12.5% of the air is added to the flame in a third zone of the burner located down stream from the second zone, and the remainder of the air is added to the flame in a fourth zone of the burner located down stream from the third zone.

68. The process of claim 67 wherein controlled amounts of the water are injected into the combustion chamber at multiple locations in the combustion chamber downstream from the fourth zone of the burner.

69. The process of claim 66 wherein controlled amounts of the water are also injected into the compressed air prior to mixing of the air with the fuel.

70. The process of claim 66 wherein, prior to mixing the air with the fuel, the compressed air is heated by heat radiating from the combustion chamber by passing said compressed air through a channel external to the combustion channel, at least one wall of the chamber being an outer wall of the combustion chamber.

71. The process of claim 67 wherein, prior to mixing the air with the fuel, the compressed air is heated by heat radiating from the combustion chamber by passing said compressed air through a channel external to the combustion channel, at least one wall of the chamber being an outer wall of the combustion chamber.

72. The process of claim 71 wherein the working fluid exiting the work engine contains less than 3 ppm NO_x.

73. The process of claim 71 wherein the working fluid exiting the work engine contains less than 3 ppm CO.

74. The process of claim 71 wherein the working fluid exiting the work engine contains less than 3 ppm CO and less than 3 ppm NO_x.

75. A generating system comprising

a) a combustion chamber,

b) fuel supply means for delivering fuel to the combustion chamber,

c) air supply means for delivering compressed air at an elevated temperature and at a constant pressure to the combustion chamber the amount of air being chosen so that at least about 90% of the oxygen in the air is consumed when burned with the fuel, the fuel and air being mixed in the combustion chamber,

d) control means to vary the quantity of air supplied to the combustion chamber and to adjust the amount of fuel supplied to the combustion chamber so that the fuel to air ratio remains constant,

e) a fuel igniter for igniting the mixture of fuel and air to produce a combustion vapor stream,

f) liquid supply means for delivering superheated water under pressure to the combustion chamber, the water being converted substantially instantaneously upon entering the combustion chamber to steam, the delivery and formation of steam creating turbulence and mixing in the combustion chamber resulting in a working fluid composed of steam, combustion products and non-flammable materials in the air and fuel, said working fluid being a high temperature steam stream deliverable to an external piece of equipment at a controlled pressure required by that external piece of equipment,

g) a combustion chamber temperature controller, said controller delivering the superheated water to the combustion chamber in quantities sufficient to maintain the temperature of the working fluid at a desired level, substantially all of the control of the temperature in the combustion chamber being derived from the latent heat of vaporization of the water introduced into the combustion chamber, and

h) heat exchanging means for transferring heat from the working fluid exiting the work engine to the water, said heat elevating the temperature of the water from a feed temperature to the desired temperature for delivery to the combustion chamber.

76. A method of operating a power generating system comprising the steps of:

compressing ambient air into compressed air having a pressure of at least about four atmospheres, and having an elevated temperature;

delivering the compressed air into a combustion chamber;

injecting controlled amounts of fuel into the combustion chamber;

injecting controlled amounts of a non-flammable liquid into the combustion chamber;

independently delivering additional non-flammable liquid to the compressed air prior to introduction of the compressed air into the combustion chamber;

independently controlling the amount of compressed air, the amount of fuel injected, and the amount of liquid injected so as to combust the injected fuel and at least a portion of the compressed air and to transform the injected liquid into a vapor;

wherein a working fluid consisting of a mixture of a non-flammable components of the compressed air, fuel combustion products and vapor is generated in the combustion chamber during combustion at a predetermined combustion temperature.

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